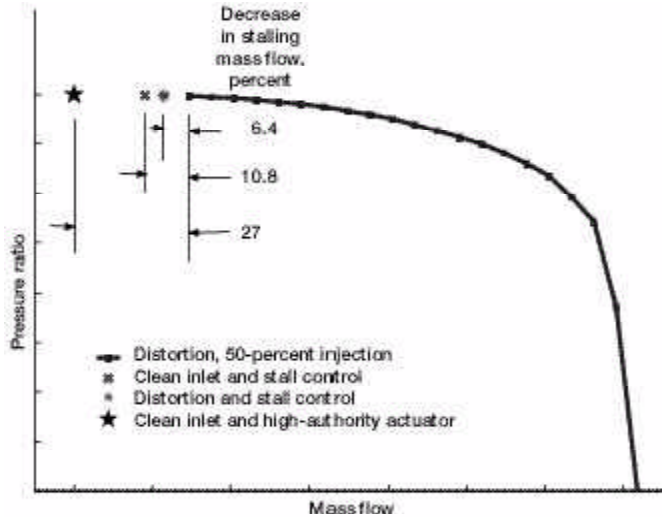
Active Control of Rotating Stall Demonstrated for a Multistage Compressor With Inlet Distortion

Aircraft compressors can suffer debilitating consequences as a result of rotating stall and surge events caused by inlet distortions. This is particularly true of aircraft during takeoff, when the compressor is operating at peak performance close to the surge line. Significant research has been conducted by the NASA Glenn Research Center in the area of compressor stability enhancement through active and passive control methods (refs. 1 to 4). Most recently, an experiment was conducted at the Wright Patterson Air Force Base Research Laboratory on a two-stage fan with inlet guide vanes and inlet distortion.

In this joint Small Business Innovation Research effort between Scientific Systems and Glenn, control of rotating stall was demonstrated in a multistage transonic fan. This two-stage fan with inlet guide vanes was tested under clean and distorted inlet conditions. The compressor was also configured with a circumferential distortion screen capable of 180° of distortion and with 14 high-velocity injectors upstream of the first rotor. Twelve of these injectors could oscillate up to frequencies of 450 Hz. The additional two injectors were located next to each other and were used in concert with each other as a single, on/off, high-authority actuator.



Stabilized compressor characteristics with and without active stall control.

In a first test of injection in this multistage environment, 12 of the valves were opened 50 percent of their full stroke to assess steady injection through the compressor. This baseline injection is shown in the compressor characteristic of the following figure, and stall margin improvements are tracked from this baseline condition. The compressor was then tested with clean inlet conditions using 12 injectors and active control. Pressure disturbances were tracked before rotating stall, and a constant gain control scheme reduced the stalling

mass flow by 10.8 percent over the baseline. With the distortion screen present in the inlet, a pole-zero cancellation control scheme was used to achieve a 6.4-percent decrease in stalling mass flow. These improvements also are shown in the figure.

In a final experiment, actively controlled, high-frequency injection from the 12 valves was used in conjunction with the high-authority actuators. In this test, the stalling mass flow of the compressor was reduced by 27 percent as indicated in the graph. These results were obtained by injecting less than 2 percent of the total compressor throughflow into the rotor tip region via 14 injection ports. These results mark the first successful demonstration of actively controlled air injection as a stall-control strategy for multistage compressors operating at speeds typical of an actual gas turbine engine.

A goal of continuing research is to determine the combination of air-injection parameters and control strategies that are most effective in providing stall control for both clean and distorted inlet flow conditions for multistage environments. Other goals include the demonstration of stall control at many locations along the core compressor and development and application of active stall control strategies that will be integral flightworthy components of onboard engine hardware.

References

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